CALFED Science Program – Putting Climate Change Into the Mix

- Cliff Dahm
- Steven Culberson
- CALFED Science Program Staff
- CALFED supports research via competitive grants and postdoctoral and predoctoral fellowships
- CALFED Science Conference 2008 – October 22-24

CALFED BAY-DELTA PROGRAM

USGS science for a changing world

Outline for Talk

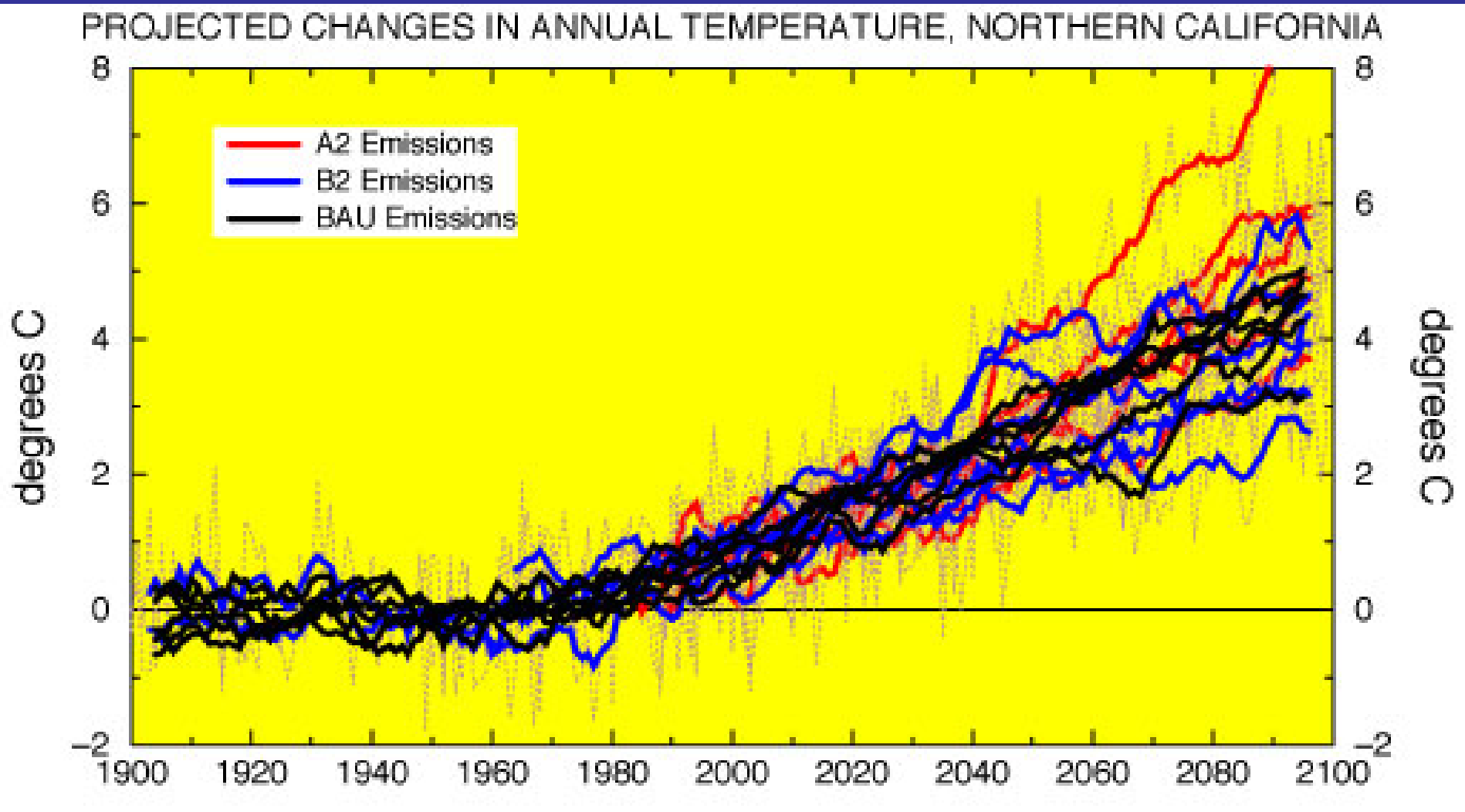
1. Climate Change and Growing Pressures on the California Delta
2. Climate Change and Water Budgets of Rivers and Floodplains
3. Climate Variability and Change - Perspectives on Ecosystem Responses

"The Next Season" – Barbara Coleman

"Wicked Problems"

Some problems are so complex that you have to be highly intelligent and well informed just to be undecided about the them – Laurence J. Peter in Conklin (2006)

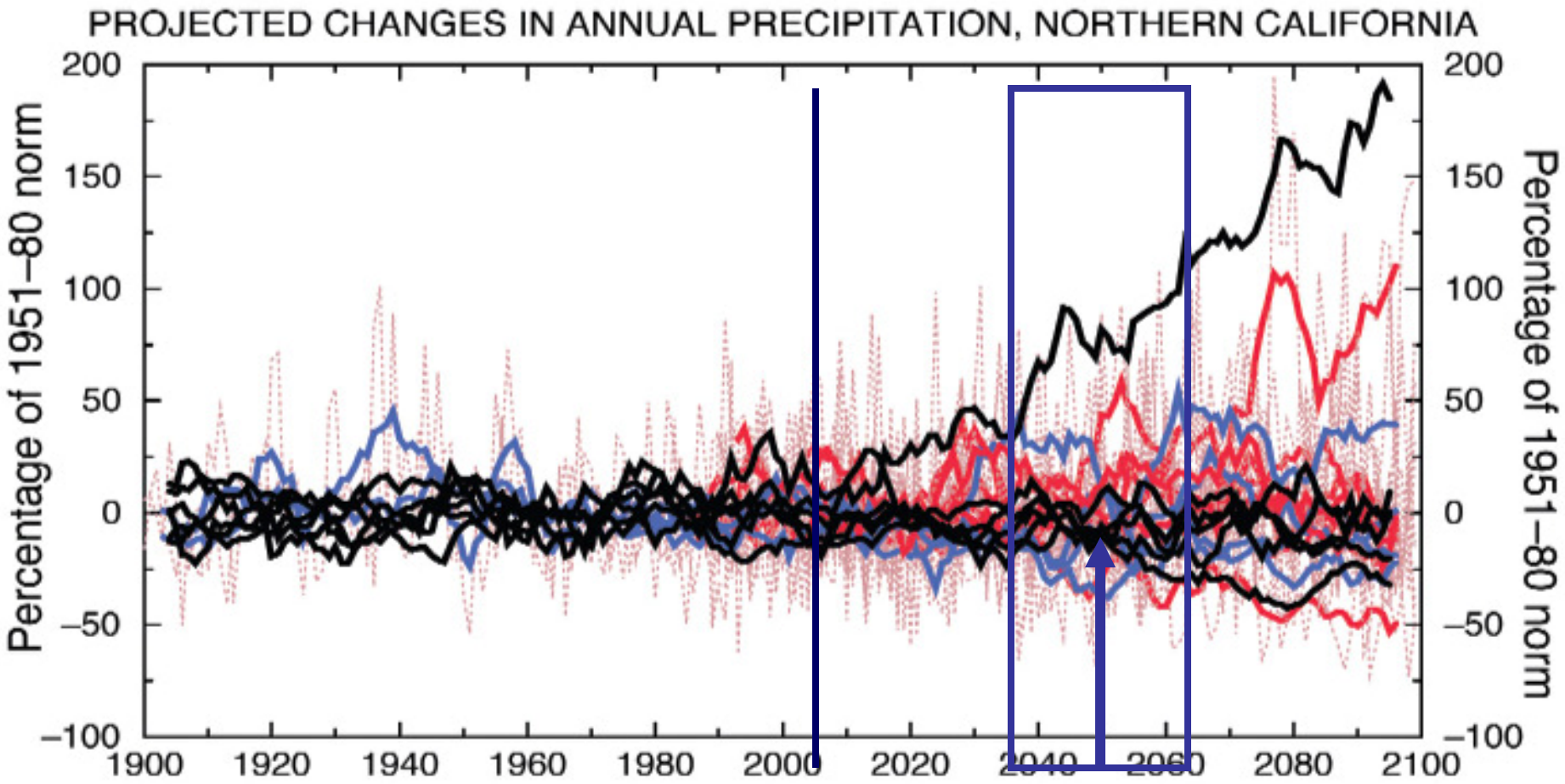
Projected Changes in Annual Temperature for Northern California



Courtesy of Mike Dettinger, USGS / Scripps.

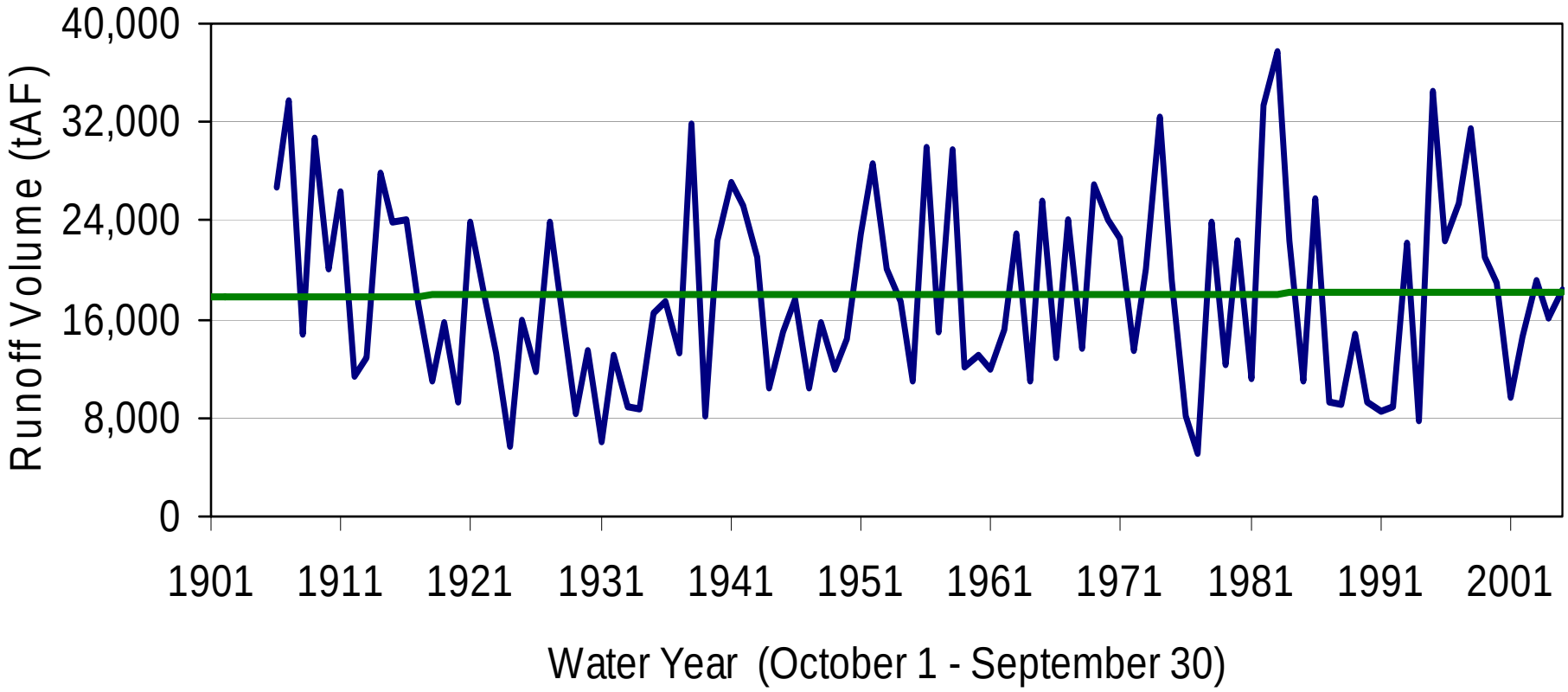
Dettinger M.D. 2005. From climate change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science. Vol. 3, Issue 1, (March 2005), Article 4. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4

Projected Changes in Annual Precipitation in Northern California



From Dettinger (2005)

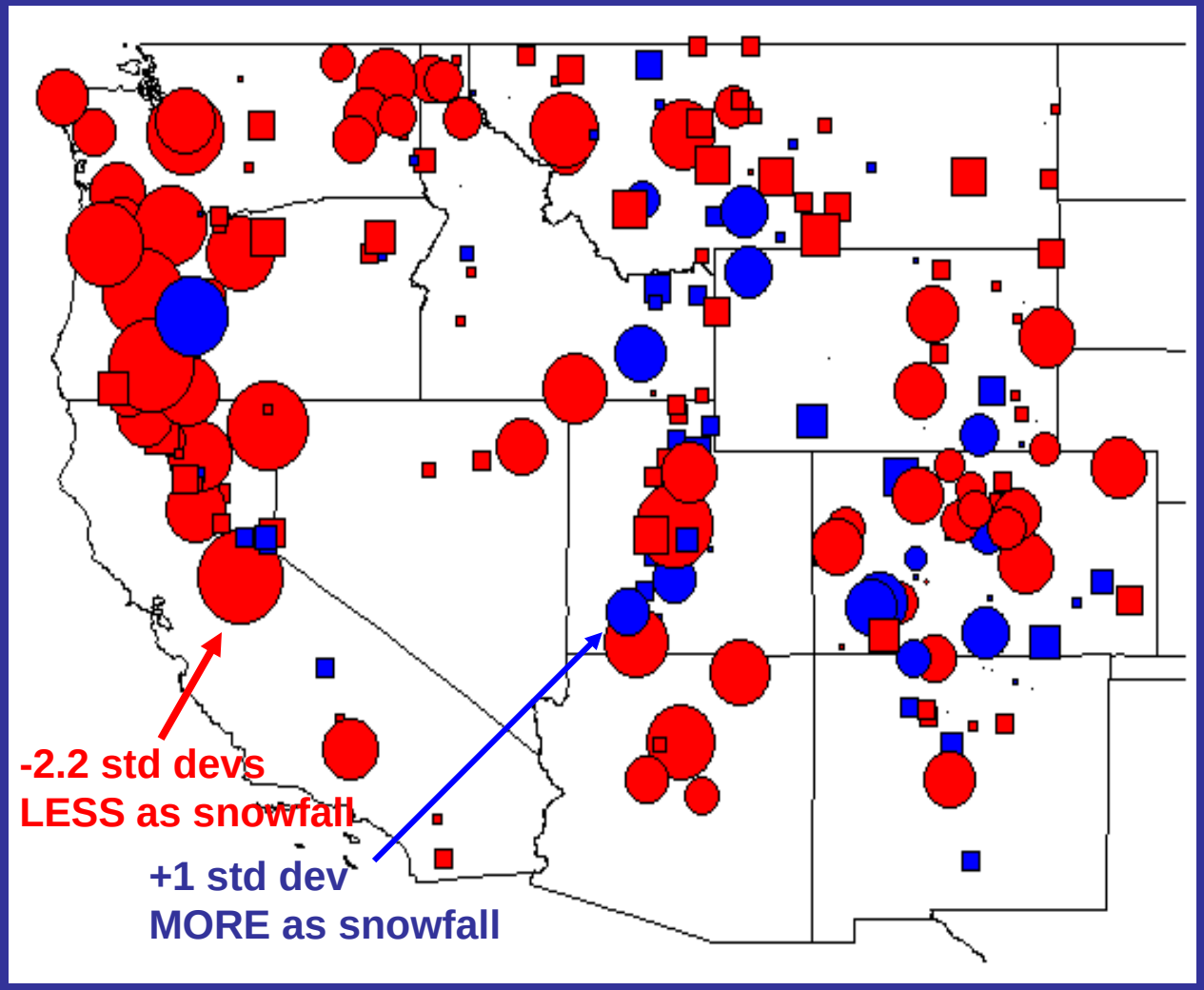
Runoff Volume in Acre Feet for the Sacramento River by Water Year



Michael Anderson DWR – 2006 CALFED Science Conference

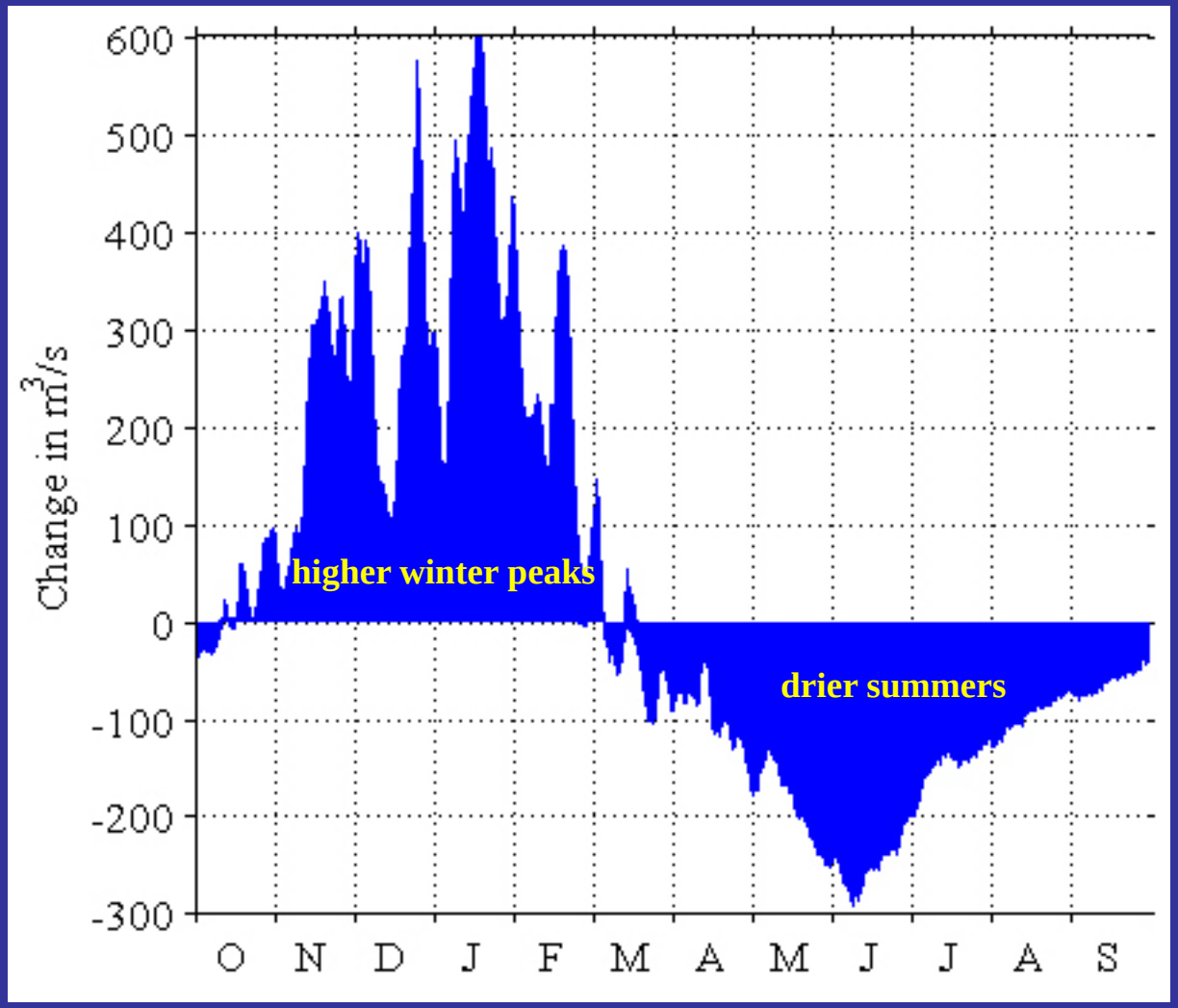
Recent warming has already driven trends towards more rain/less snow at seasonal scale.

--> Less winter snow/winter precipitation



Knowles et al. (2006) Journal of Climate

Estimated Change in Delta Flow by 2060 (relative to present day)



(assuming no change in management practices)

Knowles and Cayan (2004)

Climate Drivers - ENSO, PDO, & NAM

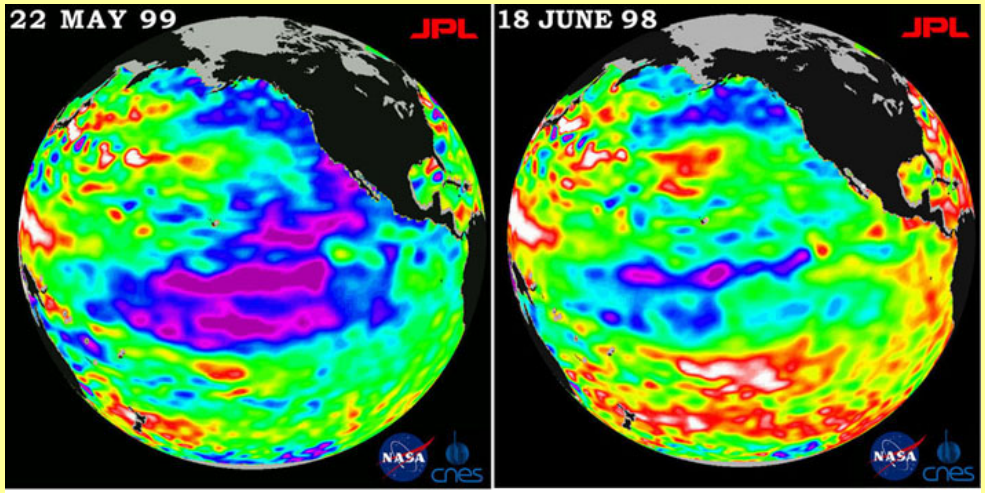
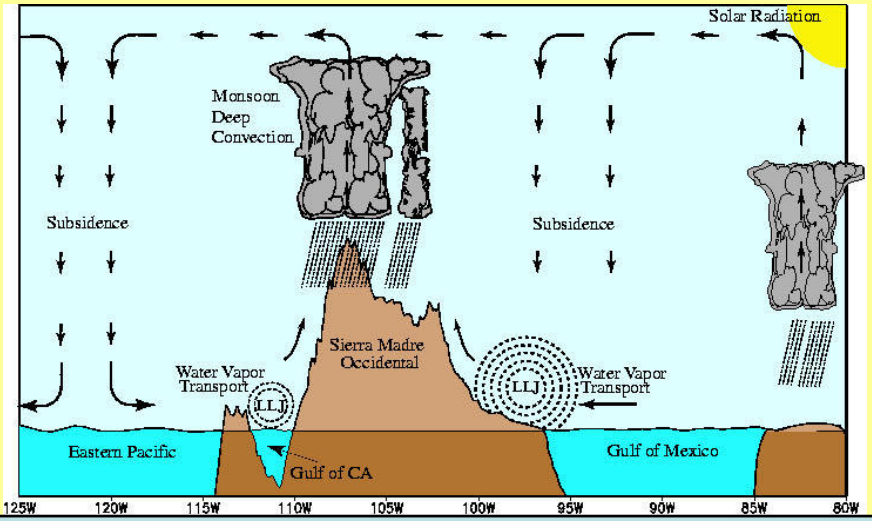
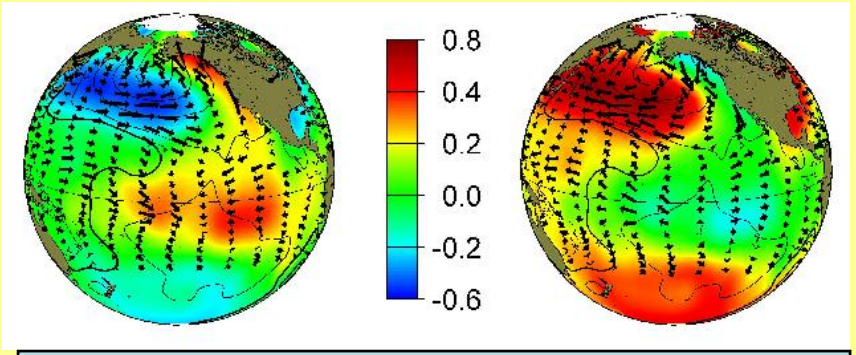


Fig.13 A very strong La Nina is pictured on the left; a weak La Nina event can be seen on the right

Strong and Weak La Niña



North American Monsoon – NOAA Figure



Mantua et al. (1997)
Pacific Decadal Oscillation (PDO)

Dai et al. 2004. Journal of Hydrometeorology 5:1117-1130.

"Together, the global land areas in either very dry or very wet conditions have increased from ~20% to 38% since 1972, with surface warming as the primary cause after the mid-1980s."

Climate Change and the California Delta

CALFED Science Conference 2006

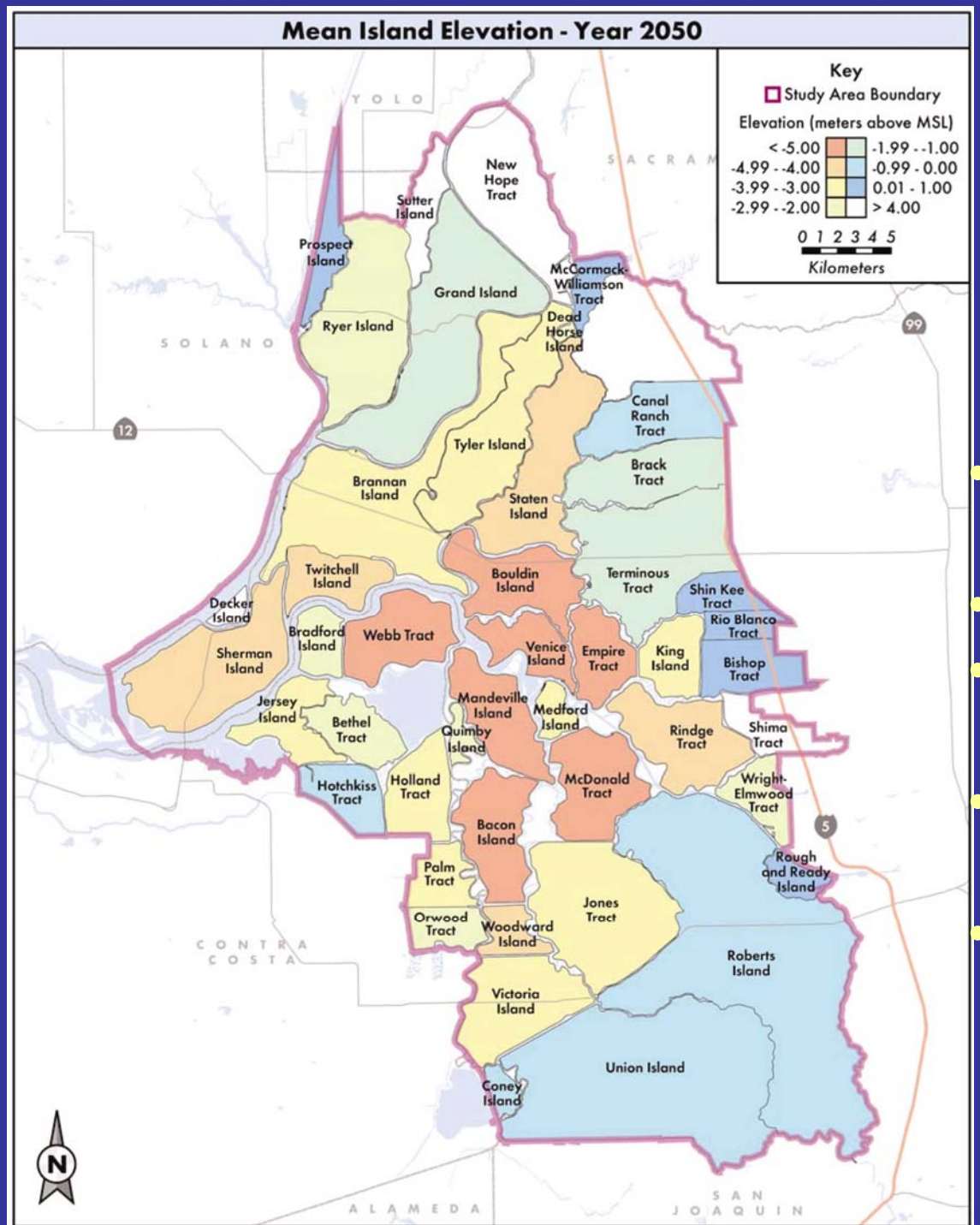
Climate Change Session

Cayan: Open coast sea level has risen ~20 cm during the last century; projected sea level rise this century of 20-80 cm; winter storms coinciding with “high” high tides accentuates risk in the Delta

Dettinger: Warming will increase scope and magnitude of rain-driven flooding from the Sierra Nevada; storm-time snow line an important concern

Knowles: Most newly inundated areas will be intertidal on Delta periphery; sea level rise plus higher winter flows increase risk of Delta levee failure

Mean "Island" Elevations for the California Delta

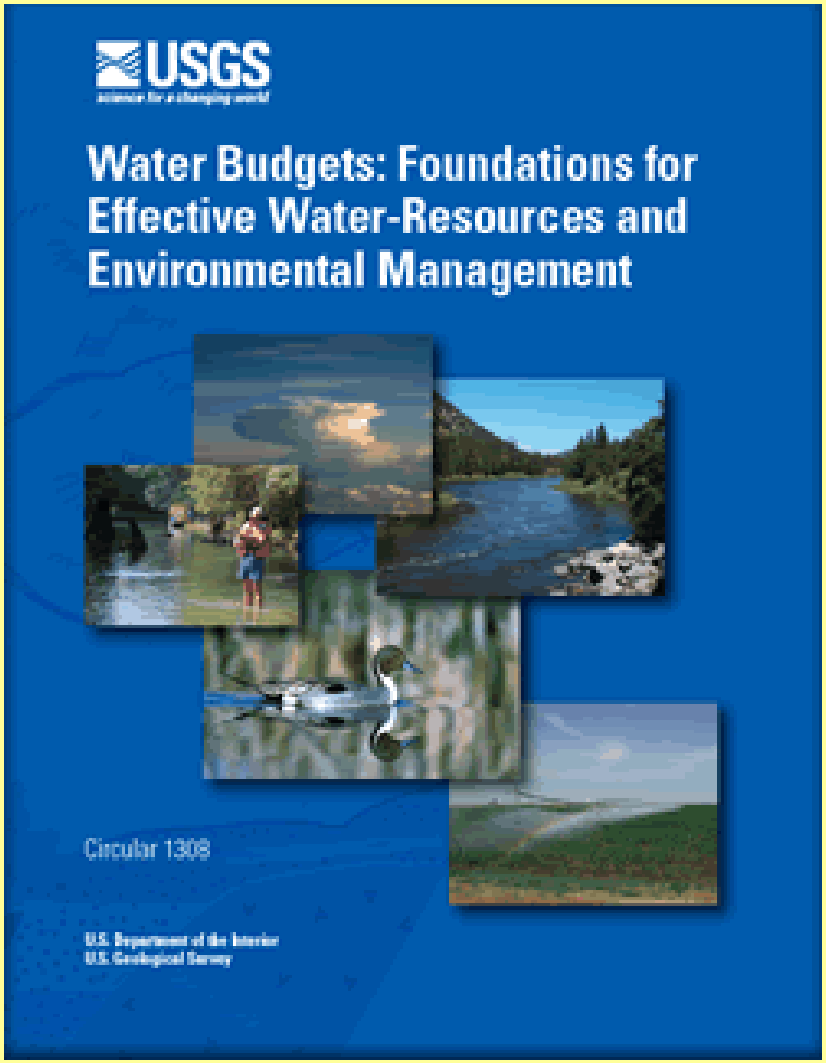


Mount and Twiss (2005) SFEWS

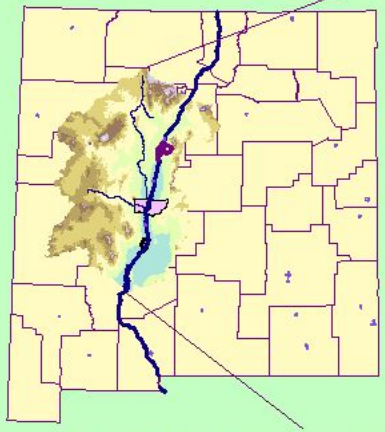
Major Sources of Risk to the Delta

- Seismic Events
- Floods
- Rising Sea Level
- Aging Levees
- Ecosystem Collapse

Water Budgets and Effective Water Resource and Environmental Management



- How much water do humans use?
- How much water do ecosystems need to flourish?
- How does the hydrologic cycle naturally change over time?
- In what ways do human activities affect the hydrologic cycle?
- How will changes in the hydrologic cycle affect water availability and use?



100 0 100 200 300 Kilometers

Otowi Bridge

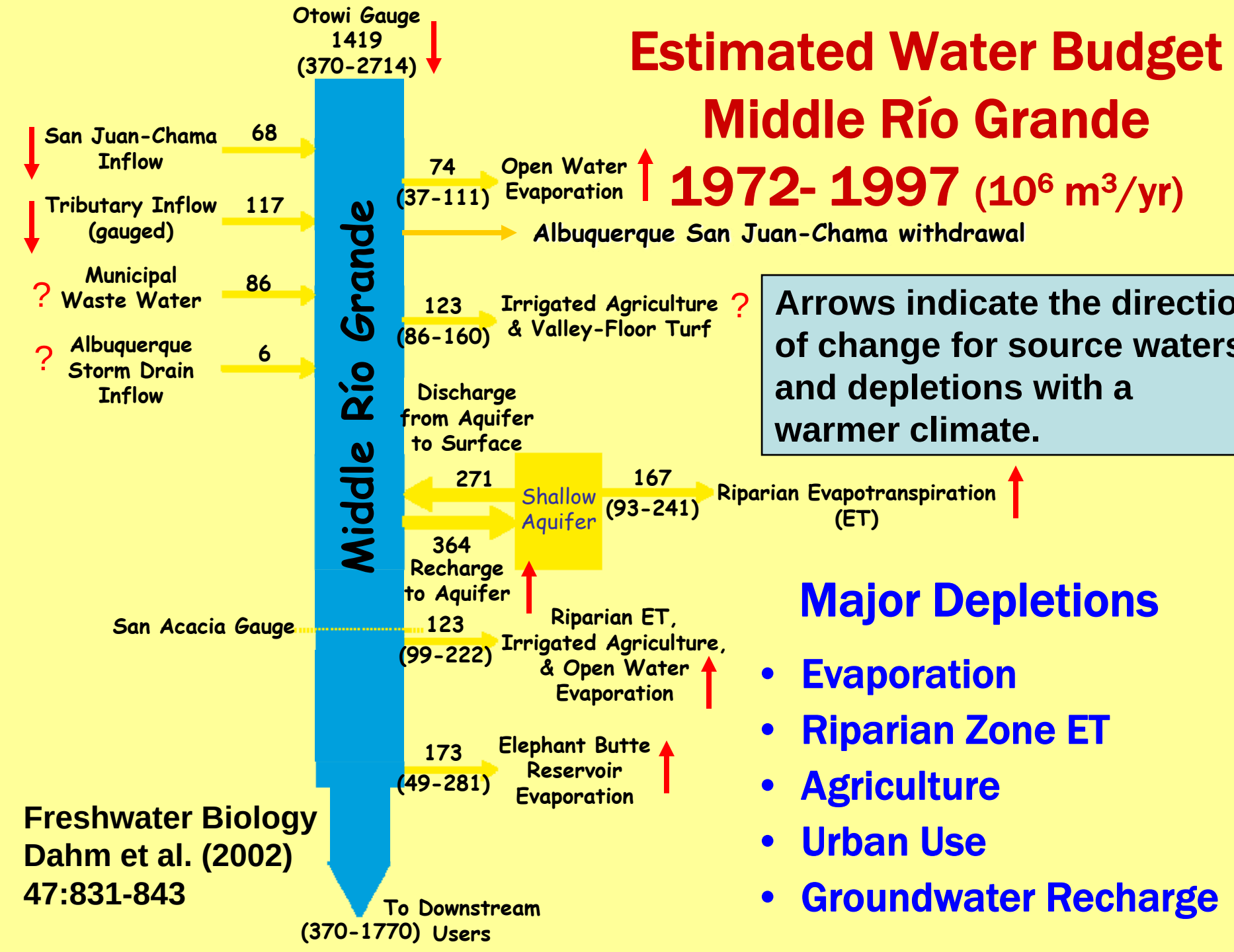
Elephant Butte

50 0 50 100 150 Kilometers

W E S

MIDDLE RIO GRANDE BASIN

Estimated Water Budget Middle Río Grande 1972- 1997 (10^6 m^3/yr)



Arrows indicate the direction of change for source waters and depletions with a warmer climate.

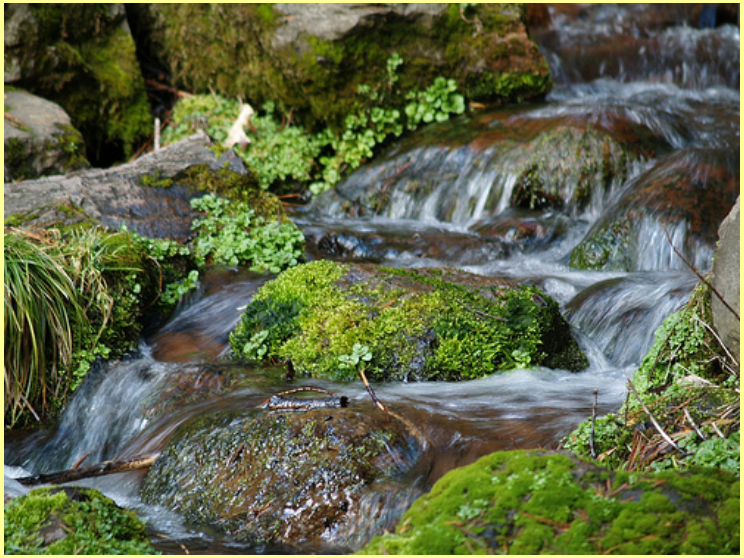
Major Depletions

- Evaporation
- Riparian Zone ET
- Agriculture
- Urban Use
- Groundwater Recharge

Freshwater Biology
Dahm et al. (2002)
47:831-843

Global Change & Snowmelt Rivers

California Delta



Sacramento River Headwaters

Snowmelt Rivers

- Particularly vulnerable to global warming (timing and quantity)
- Relied upon by one-sixth of Earth's human population
- Smaller snowpack throughout the Sierra Nevada and Rocky Mountains
- Western US will likely warm on average by ~5°C by 2100

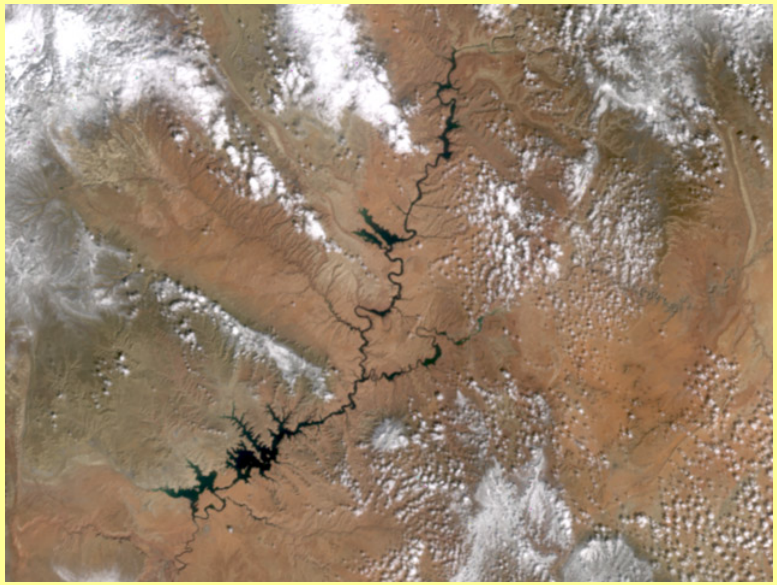
Snowmelt Rivers and Climate Change

Colorado River Basin

Christensen et al. 2004

Climatic Change 62:337-363

- Effects on hydrology and water resources using downscaled climate simulations
- Warming of 1.0 to 2.4ºC decreases annual runoff from 14-18%
- Model predictions of precipitation change over the interior of continents range from substantial (>20% annual average) decreases to increases



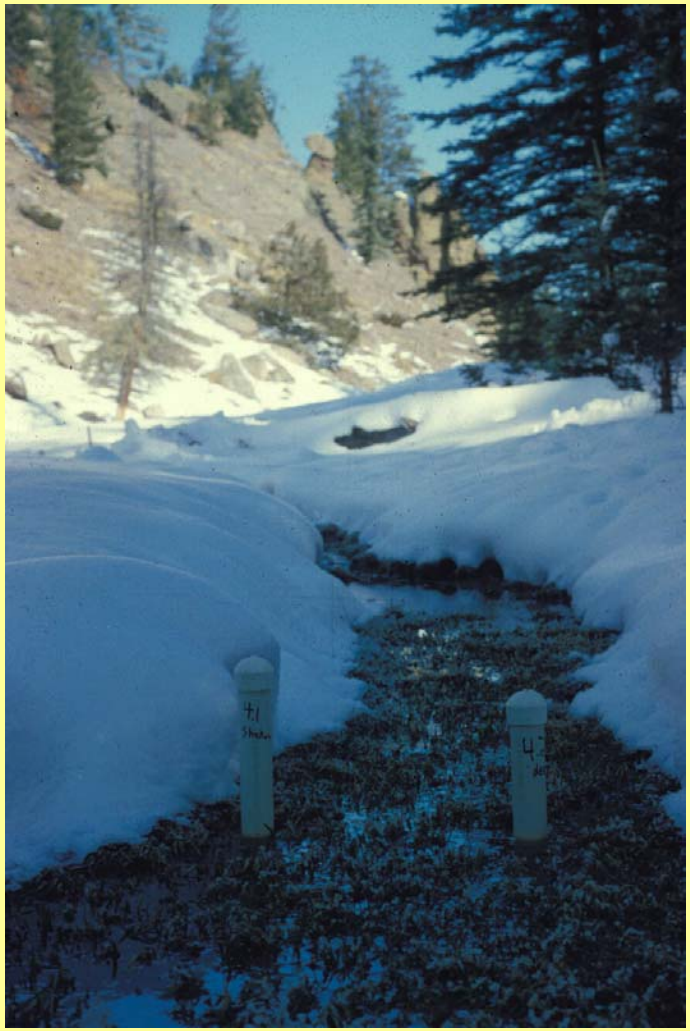
Climate Change Interactions in Riverine Landscapes

"Consideration of land-water interactions and interactions between climate warming and other human stresses are important for the accurate prediction of the effects of climatic change." Schindler 1997 Hydrological Processes

Climate Warming Interacts With:

- **Non-native Species**
- **Altered Biogeochemistry**
- **Reservoirs**
- **Population Growth**
- **Stratospheric Ozone Loss**
- **Contaminants and Toxins**
- **Infectious Disease**
- **Eutrophication**
- **Fisheries**
- **Land-use Change**
- **Acid Precipitation**
- **Drought**

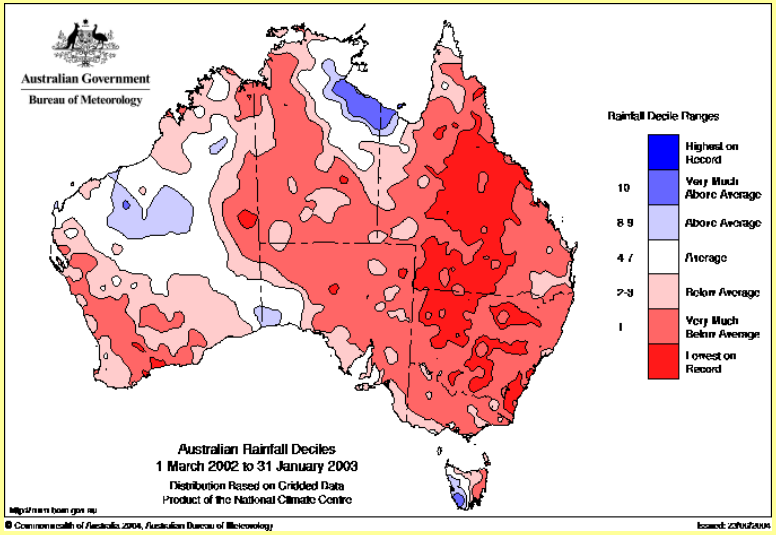
Drought and Temperature – 1
SW US and Southern California



"The most severe future droughts will still occur during persistent La Niña events, but they will be worse than any since the Medieval period because the La Niña conditions will be perturbing a base state that is drier than any experienced recently."

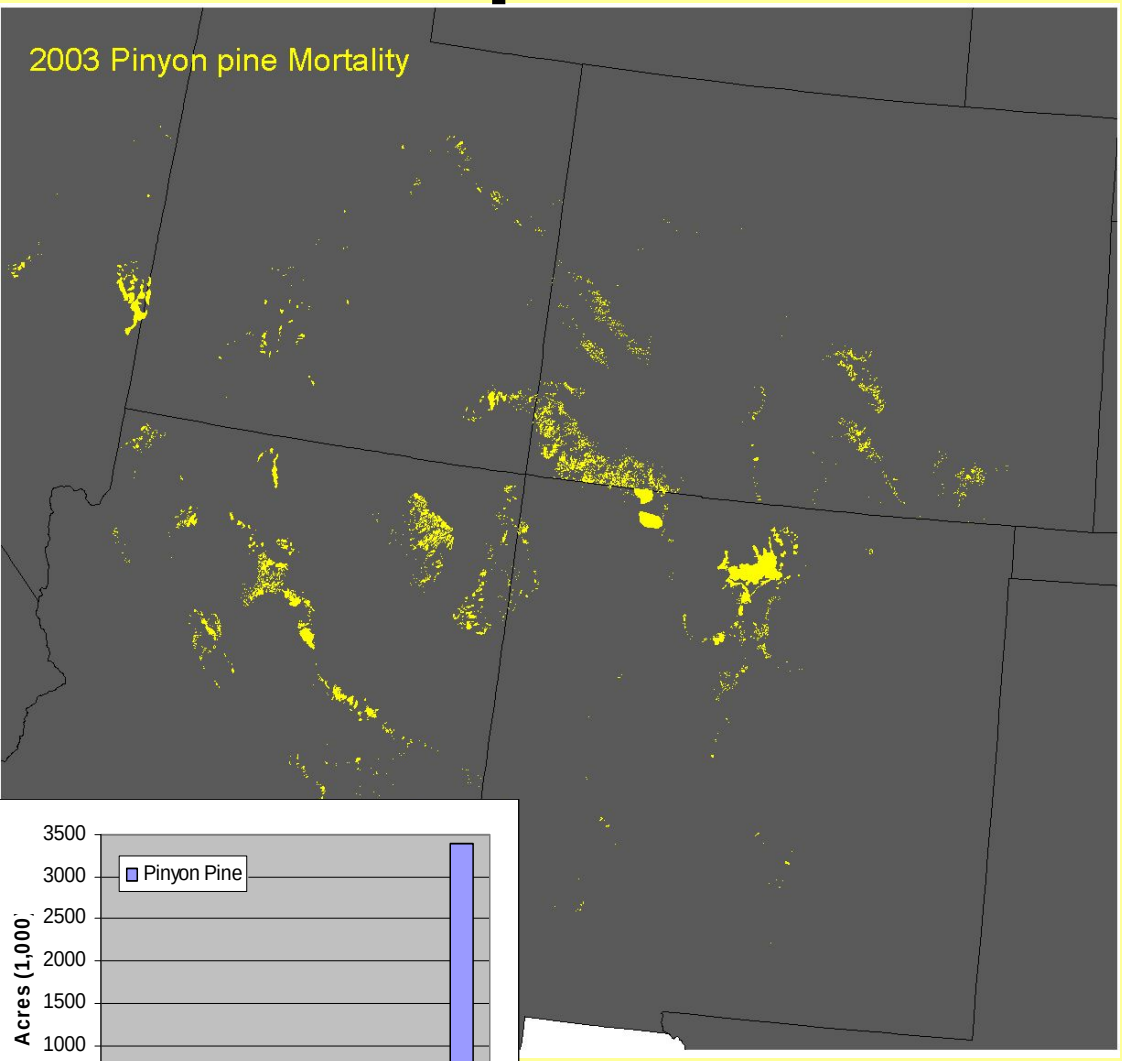
Seager et al. (2007) Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. Science – April 5, 2007 316:1181-1184.

Drought and Temperature – 2
An Example from Australia



"The possibility that the enhanced greenhouse effect is increasing the severity of Australian droughts, by raising temperature and hence increasing evaporation, even if rainfall does not decrease, needs to be considered." N. Nicholls 2004. Climatic Change 63:323-336.

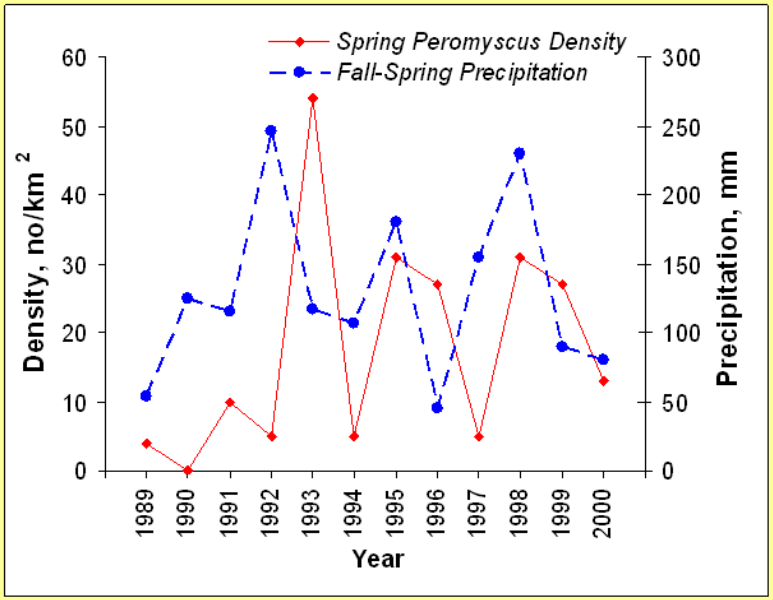
Drought and Temperature – 3
An Example from the southwestern US



D.D. Breshears et al. 2005 PNAS 102:15144-15148

"This recent drought episode in southwestern North America may be a harbinger of future global-change-type drought throughout much of North American and elsewhere, in which increased temperature in concert with multidecadal drought patterns associated with oceanic sea surface oscillations can drive extensive and rapid changes in vegetation and associated land surface properties."

Climate, the ENSO Phenomenon, the Sevilleta LTER, and Emergent Disease



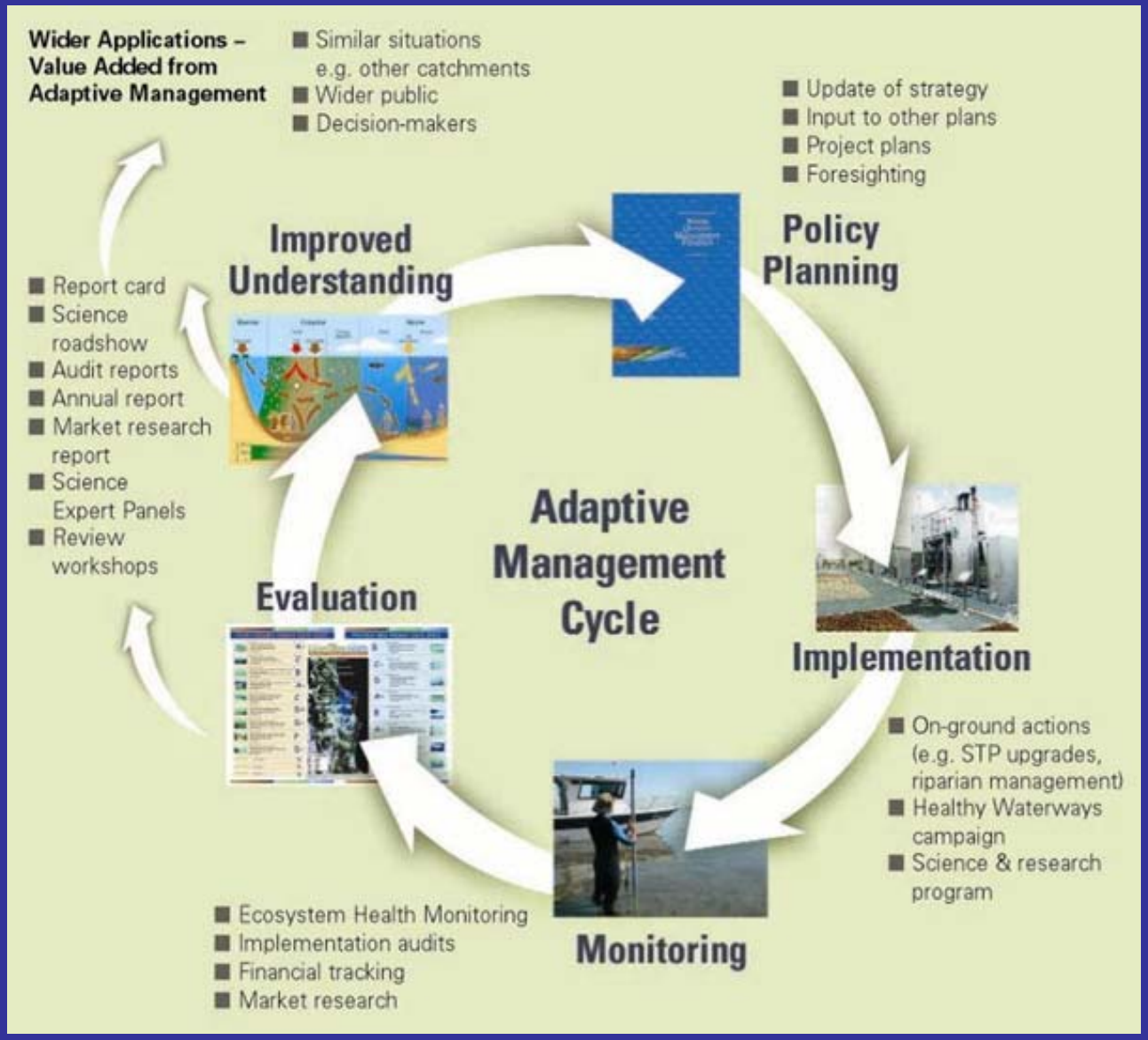
- **"Evidence from two El Niño episodes in the American Southwest suggests that El Niño-driven precipitation, the initial catalyst of a trophic cascade that results in a delayed density-dependent rodent response, is sufficient to predict heightened risk for human contraction of hantavirus pulmonary syndrome."**
- **Yates et al. 2002. The Ecology and Evolutionary history of an Emergent Disease: Hantavirus Pulmonary Syndrome. BioScience 52:989-998.**

Ecosystem Health Monitoring Program

Freshwater Ecosystem Health Monitoring Program - Implemented 2002

120 freshwater sites (sampled 2x/yr)

Adaptive Management Framework –SE Queensland

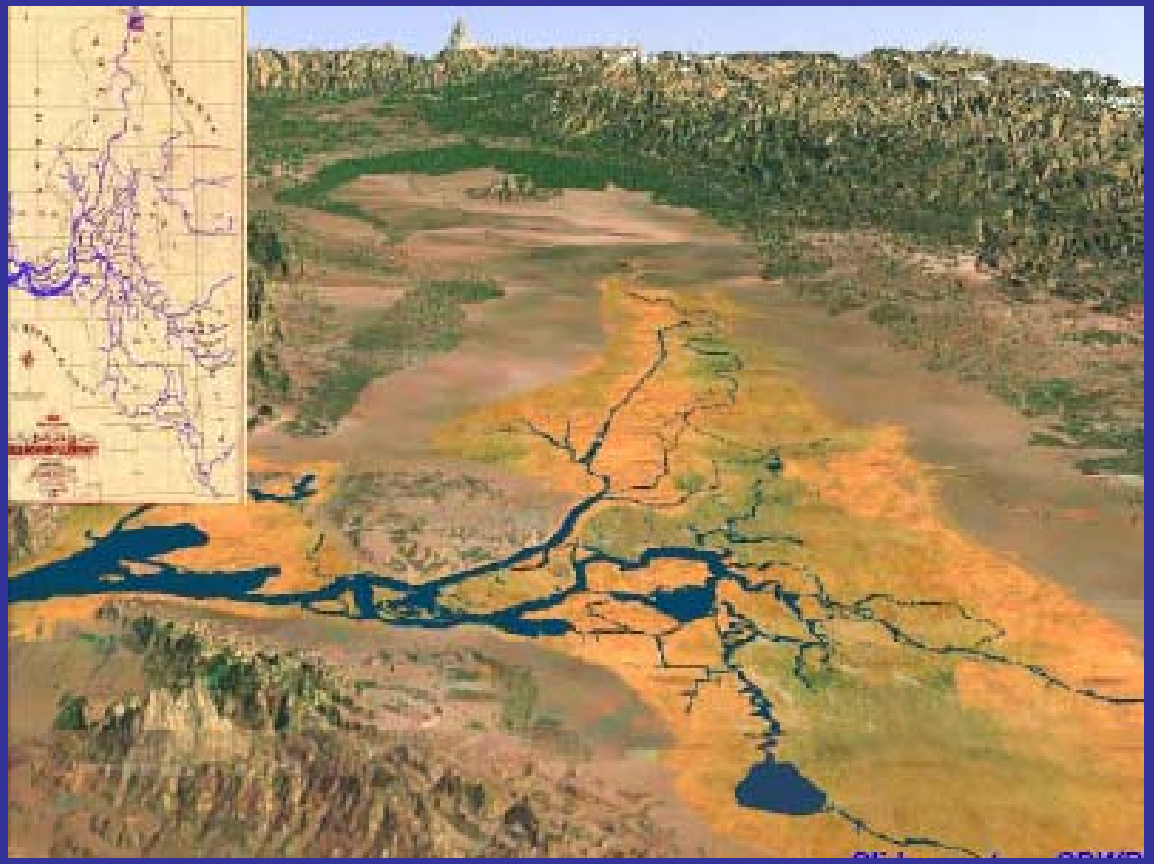


- ongoing knowledge acquisition
- critical role of monitoring
- continuous improvement in the identification and implementation of management.
- effective communication of knowledge for policy/planning

Estuaries Are Complex Landscapes Responding to the Complexities of Climate Change – A Wicked Problem[2]

Ecosystem Impacts

- Changing Water Budgets and Hydrographs
- Shifts in Thermal Regimes
- Behavioral Cues for Plants and Animals
- Thresholds and Alternate Stable Ecosystems
- Emerging Diseases
- Endangered Species
- Non-native Species



Acknowledgements

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